

# A Class File for AIP The parameter section

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# Transverse Single Spin Asymmetry Measurement with $J/\Psi$ in Polarized p+p Collisions at RHIC

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**Abstract.** The PHENIX experiment has measured transverse single spin asymmetry of  $J/\Psi$  in polarized p+p collisions at forward rapidity at  $\sqrt{s} = 200$  GeV. The data were collected from year 2006 run of RHIC with average beam polarization of 56%. At RHIC energy, heavy quark production is dominated by gluon gluon interaction. Therefore, the transverse single spin asymmetry in  $J/\Psi$  production can provide a clean measurement of the gluon Sivers distribution function.

**Keywords:** Proton structure, transverse spin

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## INTRODUCTION

The measurement of transverse single spin asymmetries gives us an opportunity to probe the quark and gluon structure of transversely polarized nucleons. Large transverse single spin asymmetries of up to 20% - 40% were observed for pions produced at large  $x_F$  at  $\sqrt{s} = 20$  GeV [1] and have been found to persist at  $\sqrt{s} = 200$  GeV by the STAR [2] and BRAHMS [3] experiments, although they were expected to vanish in pQCD calculations at the leading order. A number of pQCD based models have been developed to explain this phenomenon. Among them are the Sivers effect (transversely asymmetric  $k_T$  quark and gluon distributions) [4], the Collins effect (transversity distribution in combination with spin-dependent fragmentation function) [5], and the higher twist effect (interference between quark and gluon fields in the initial or final state) [6, 7].

At RHIC energy, heavy flavor production is dominated by gluon-gluon interaction, thus Collins effect has minimum impact on  $A_N$  as the gluon's transversity is zero. Therefore, the production of heavy flavor particles in transversely polarized p+p collisions at the PHENIX experiment offers a good opportunity to probe the gluon's Sivers effect.

## MEASUREMENT AND ASYMMETRY CALCULATION

In this report we present the latest results of transverse single spin asymmetry in  $J/\Psi$  production in polarized p+p collisions at RHIC. The PHENIX muon spectrometers have measured  $J/\Psi$  yields through the  $J/\Psi \rightarrow \mu^+ \mu^-$  channel at forward rapidities ( $1.2 < |\eta| < 2.4$ ). During the recent 2006 polarized pp run, the PHENIX experiment has collected  $2.7 \text{ pb}^{-1}$  data with transverse beam polarization of about 56%. The Level-2 filtered data sample has been used in this analysis.

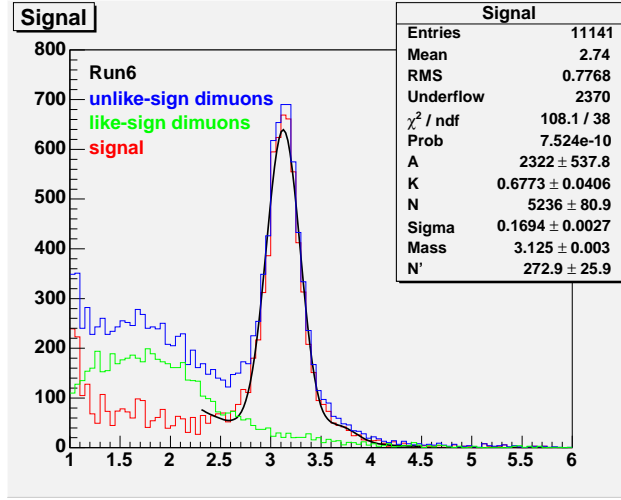


FIGURE 1. Dimuon invariant mass distribution.

The  $J/\Psi$  yield is obtained by fitting the dimuon mass spectrum with a single exponential background plus two gaussian functions (for  $J/\Psi$  and  $\Psi'$ ) in the mass range 2.3 GeV - 4.5 GeV (as shown in figure 1). The total Number of  $J/\Psi$  from this fit is  $5236 \pm 81$ . The Monto Carlo simulation shows the systematic error in determining  $J/\Psi$  yield is less than 2%.

The transverse single spin asymmetry  $A_N$  can be determined by:

$$A_N = \frac{1}{P_b} \frac{\sigma^\uparrow - \sigma^\downarrow}{\sigma^\uparrow + \sigma^\downarrow} = \frac{1}{P_b} \frac{N^\uparrow - RN^\downarrow}{N^\uparrow + RN^\downarrow}, \quad (1)$$

where  $P_b$  is the beam polarization,  $\sigma^\uparrow(\sigma^\downarrow)$  is the production cross section,  $N^\uparrow(N^\downarrow)$  is the  $J/\Psi$  yield from up(down) polarized bunches, and  $R = L^\uparrow/L^\downarrow$  is the relative luminosity of bunch crossings of opposite polarization sign. The relative luminosity is measured by two global detectors, BBC and ZDC.

Alternatively, we also use square root formula

$$A_N = \frac{1}{P_b} \frac{\sqrt{N_L^\uparrow \cdot N_R^\downarrow} - \sqrt{N_L^\downarrow \cdot N_R^\uparrow}}{\sqrt{N_L^\uparrow \cdot N_R^\downarrow} + \sqrt{N_L^\downarrow \cdot N_R^\uparrow}}, \quad (2)$$

to cross check our results.

The asymmetry of  $J/\Psi$  was determined for each fill using Eq. (1), then averaged over all fills.

The raw  $J/\Psi$  sample is contaminated by other background, mainly comes from Drell-Yan process, open charm and light hadrons decay. The  $A_N^{J/\Psi}$  was corrected for the contribution of background by using

$$A_N^{J/\Psi} = \frac{A_N^{incl} - r \cdot A_N^{BG}}{1 - r}, \quad (3)$$

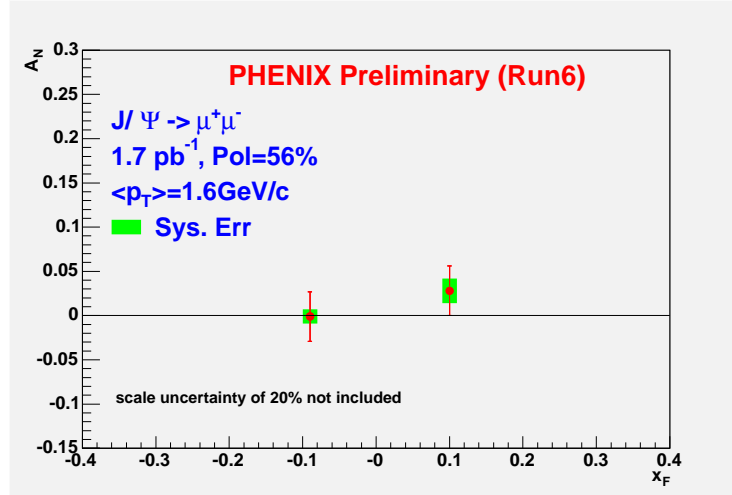
$$\delta A_N^{J/\Psi} = \frac{\sqrt{(\delta A_N^{incl})^2 + r^2 \cdot (\delta A_N^{BG})^2}}{1 - r}, \quad (4)$$

where  $r$  is the background fraction under the  $J/\Psi$  peak,  $A_N^{BG}$  is the averaged background asymmetry.  $A_N^{BG}$  is obtained using the like (unlike) sign dimuon pairs within  $2.0 \text{ GeV} < M_{\mu\mu} < 2.5 \text{ GeV}$ , and like sign dimuon pairs within  $2.8 \text{ GeV} < M_{\mu\mu} < 3.5 \text{ GeV}$ .

The systematic uncertainty has been checked with bunch shuffling technique with randomly assigned polarization direction for bunches in each fill. The bunch-to-bunch and fill-to-fill systematic errors are much smaller than the statistical errors for this data set.

## RESULTS

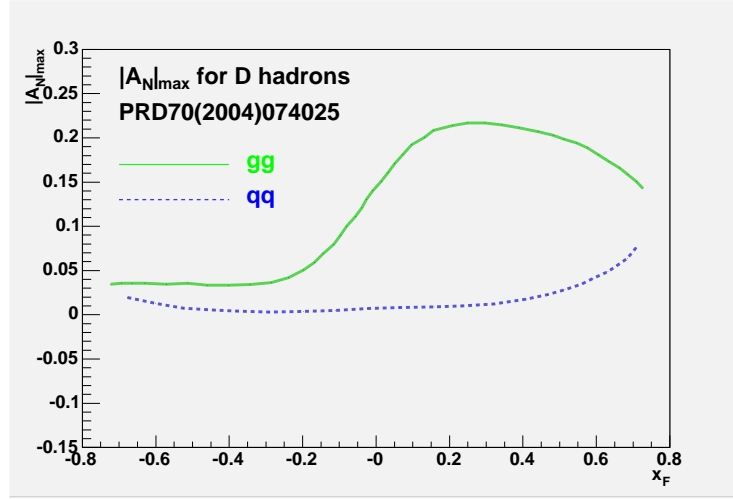
The asymmetry was calculated for two  $x_F$  bins. Figure 2 shows the preliminary result of the single spin asymmetry as a function of  $x_F$  in  $J/\Psi$  production from the 2006 RHIC transverse run. A scale uncertainty of 20% due to the absolute polarization values is not included in this analysis. Within the limits of errors,  $A_N$  is consistent with zero over the measured  $x_F$  range.



**FIGURE 2.** Transverse single spin asymmetry vs.  $x_F$  for  $J/\Psi$  at forward rapidities. A scale uncertainty of 20% is not included.

Currently there is no theoretical calculation of  $J/\Psi$ 's  $A_N$ . However, there is a prediction of maximum values of  $|A_N|$  in D meson production at fixed transverse momentum  $p_T = 1.5 \text{ GeV}/c$  at RHIC energy, as shown in figure 3[8]. The solid line shows  $|A_N|_{max}$  when the gluon Sivvers function is set to its maximum with the quark Sivvers function set to zero, and the dashed line corresponds to a maximized quark Sivvers function with the gluon Sivvers function set to zero. If the transverse single spin asymmetry comes from the initial state (the  $J/\Psi$  production mechanism does not play an important role), then we expect  $A_N$  in  $J/\Psi$  and D meson production to be similar. The fact that there is no

sizable asymmetry observed in figure 2 may indicate our results disfavor the maximum contribution of gluon's Sivers function.



**FIGURE 3.** Maximized values of  $|A_N|$  for the process  $p+p \rightarrow DX$  as a function of  $x_F$  at fixed transverse momentum  $p_T = 1.5$  GeV/c at RHIC energy.

## SUMMARY

The transverse single spin asymmetry  $A_N$  for  $J/\Psi$  has been measured for the first time at forward rapidity and  $\sqrt{s} = 200$  GeV with the PHENIX muon spectrometers. Using Level-2 dimuon triggered data sample (corresponds to 60% of the whole 2006 transverse data set), no sizable  $A_N$  of  $J/\Psi$  has been observed which indicates our results disfavor the maximum gluon Sivers contribution.

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